

LANSCCE DIVISION RESEARCH REVIEW

Recent Experience with the LEDA RFQ

JL. M. YOUNG (LANSCCE-1)

Introduction

We are preparing the radio frequency quadrupole (RFQ) for the Low- Energy Demonstration Accelerator (LEDA) to accelerate beam. The LEDA RFQ is designed to accelerate a 100-mA continuous wave (CW) proton beam from 75 keV to 6.7 MeV. This is a report on our experiences with high-power RF conditioning of the RFQ, and with initial pulsed-beam tests. The RFQ dissipates 1.2 megawatts of RF power at design fields. This 350-MHz CW RFQ has peak electrical fields of 33 MV/m on the vane tips. The average power dissipation is 13 watts/cm² on the outer walls of the RFQ near the high-energy end. The power from each klystron is split two ways to lower the stress on the RF windows. Each klystron can produce 1.3 megawatts of RF power.

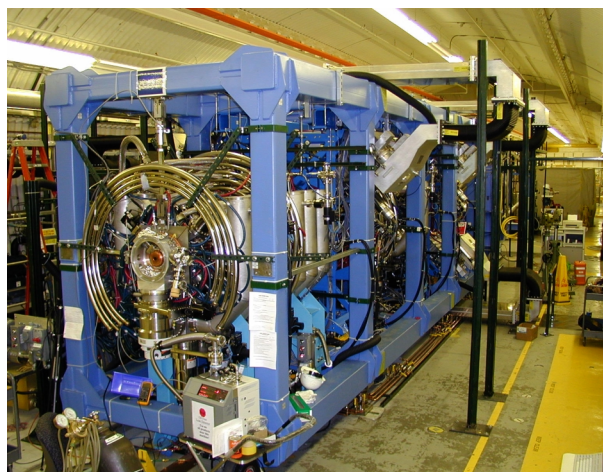
Examining Spallation Reactions in Planetary Material

The LEDA RFQ consists of four 2-meter-long RFQs resonantly coupled together to form an 8-meter-long structure. These sections are labeled A, B, C, and D starting from the low-energy end. RF drive ports are located in the B and D sections. The RF power is coupled into the RFQ through half-height WR2300 waveguide and a section of tapered, ridge-loaded waveguide to a coupling iris. The tapered waveguide has the dimensions of the half-height WR2300 waveguide at one end and tapers to only 7 inches wide at the iris to the RFQ. The gap between the ridges of the ridge-loaded waveguide slowly increases as the cross section increases in size toward the half-height WR2300 waveguide.

Initial conditioning

After an initial demonstration, high-power RF (HPRF) conditioning began in earnest about 9:00 a.m. on Nov. 20, 1998. The progress of conditioning and beam tests is summarized in Table 1. We believe that multipacting in the tapered section of the waveguide slowed progress in conditioning the RFQ. At low RF power levels the multipacting occurs close to the iris where the gap is slightly greater than 1/16 inch. As the RF power increases, the position

where the multipacting occurs moves up the taper toward the WR2300 waveguide. At the halfway point in the tapered section the gap is 2.9 cm, and simple multipacting theory indicates that multipacting can occur with the RF power equal to 68 kW. The theory indicates that this power level is about the limit for the simple half-cycle multipacting. To mitigate the multipacting problem, we have reduced the number of RF waveguide feeds by a factor of two. We are now using one klystron on section B and only feeding quadrants 3 and 4 of that section. On section D we use two klystrons, each feeding two quadrants. The new configuration is shown in Figure 1. Our original plan used one klystron per section to drive sections B, C, and D with each klystron driving all 4 quadrants of each section. Previously, with two klystrons attached to the RFQ we had to drive the RFQ with at least 800 kW to be above the power level where multipacting was a problem. If we stayed with our original plan, the multipacting would occur at up to 1.2 MW with 3 klystrons, which is our design power level without beam. By halving the number of waveguide feeds, we will be above the persistent multipacting levels that occur below ~600kW. We have restarted conditioning after making these all these changes. At this time we are still experiencing multipacting in the waveguide at RF power levels above 600kW, but it appears to be improving with RF processing.



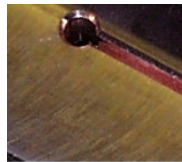
▲ Fig. 1. Picture of the RFQ taken May 29, 1999. All three klystrons are connected to the RFQ through 6 waveguides.

Iris melting

When the conditioning process resumed on January 5, we soon achieved 1.2 MW of net RF power in the RFQ. However, the reflected power on the D-section waveguide network increased to 10% instead of the 2% observed on December 24, the date of the previous test. Also, the frequency of the RFQ was 80 kHz lower than previously measured. While looking for the cause of the high reflected power, we removed the window on quadrant 3 of section D and discovered that some melting had occurred at both ends of the iris. Figure 2 is a picture of an iris removed from the RFQ in April 1999. A MAFIA Code calculation on a simplified model of the iris showed the RF currents at the ends of the iris slot were enhanced a factor of 10 over the RFQ wall current. The copper iris plate was only 1/16 inch thick at this point. This localized heating coupled with the increase in surface resistance at elevated temperatures was enough to melt the ends of the iris slots when the RFQ was operated with CW RF power at close to the design fields. The model results also showed that by increasing the thickness of the iris plate to 3/8 inch, the size of the hole at the end of the slot more than doubles for the same coupling. This change reduces the enhancement of the wall currents from a factor of 10 to only 2.5. We replaced the original 1/16-inch-thick iris plates with iris plates that are 3/8-inch thick. Figure 3 shows a picture of one of the new irises.



▲ Fig. 2. Picture of melted iris.



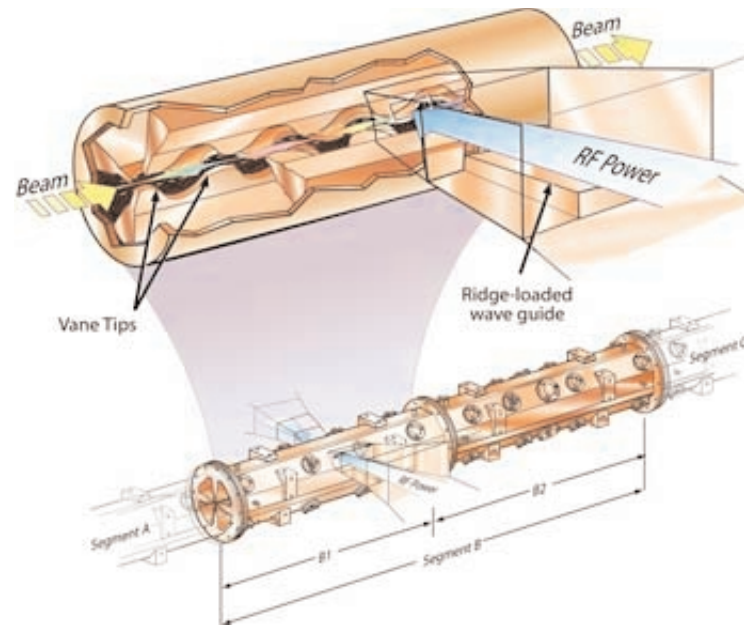
▲ Fig. 3. Picture of new iris modified to reduced RF heating.

Pulsed beam

After January 27, restricting the RF power required conditioning the RFQ with a pulsed format whenever we raised the RF fields above the design value. During this period we integrated the low-level RF (LLRF), the HPRF, and the water cooling system to reliably maintain the RF fields in the RFQ. The LLRF system sends a frequency error signal to the RFQ's water cooling system. This resonance control cooling system adjusts the temperature of the water that cools the outer walls of the RFQ to maintain the 350-MHz resonant frequency. The cooling system also supplies 50°F water to cooling channels near the vane tips.

Future Plans

On June 11, 1999, after the reconfiguration and two weeks of RF conditioning, we operated the RFQ CW with the design fields for more than 30 minutes. The ion source has now been reconnected to the RFQ and testing with pulsed beam resumed June 18, 1999. We began CW beam tests August 9, and by August 24, 1999 we had accelerated 50 mA to 6.7 MeV CW.



| Date | RF | Beam | Comment |
|----------------|---------------------------------------|--|---|
| Nov. 19, 1998 | 5 kW | No | Started RF conditioning. One klystron. |
| Nov. 23, 1998 | 100 kW | No | Multipacting in waveguides pacing progress. |
| Nov. 24, 1998 | 600 kW 67 msec. Pulse 67% duty cycle. | No | Broke through multipacting at high peak power. |
| Dec. 16, 1998 | 800 kW CW 900 kW peak with pulsing. | No | Still using only one klystron |
| Dec. 17, 1998 | No | No | Connected second klystron to RFQ. |
| Dec. 24, 1998 | 1.08 MW average 1.2 MW peak. | No | Using two klystrons. Reflected power 2% |
| Jan. 7, 1999 | 1.2 MW net in RFQ | No | Reflected power increased to 10% |
| Jan. 10, 1999 | No | No | Discovered melted irises and started RFQ re-tuning. |
| Jan. 27, 1999 | Restricted average power to <1.2 MW | No | Restart RF conditioning after retuning RFQ. |
| Mar. 15, 1999 | RFQ 1.1 MW average | No | End of RF conditioning. |
| Mar. 16, 1999 | 1.2 MW peak 90% duty | First Beam 6 mA in 4 mA out. | No steering or focusing adjustments. |
| April 8, 1999 | 60% duty | 72 mA peak, 1.5 milli-second Pulse, 10 Hz. | Saturating the klystrons output power during beam pulse. |
| April 19, 1999 | No | No | Started reconfiguration to 3 klystron with two feeds per klystron. Replaced irises. |
| June 1, 1999 | 20 kW | No | Started RF conditioning again. |
| June 11, 1999 | RF CW ~1.1 MW | No | Approximately design field-level maintained for 30 minutes. |

Table 1 Time Line of RFQ RF Conditioning and Beam Tests.

References:

J. D. Schneider, "Operation of the Low-Energy Demonstration Accelerator: The Proton Injector for APT," Proc. 1999 IEEE Particle Accelerator Conference. [New York, March 29 - April 2, 1999] pp 503-507 IEEE Catalog Number: 99CH36366

D. Schrage et al., "CW RFQ Fabrication and Engineering," Proceedings of the XIX INTERNATIONAL LINAC Conf. [Chicago, 23-28 August 1998] Argonne National Laboratory, Argonne, Illinois. ANL-98/28 pp679-683

For more information, contact Janet Sisterson (Northeast Proton Therapy Center, Massachusetts General Hospital, 30 Fruit St, Boston, MA 02114), (617) 724-1942, jsisterson@partners.org.

Produced by the LANSCE-4 communications team:
Barbara Maes, Sue Harper, Garth Tietjen,
Sharon Mikkelsen, and Grace Hollen.

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